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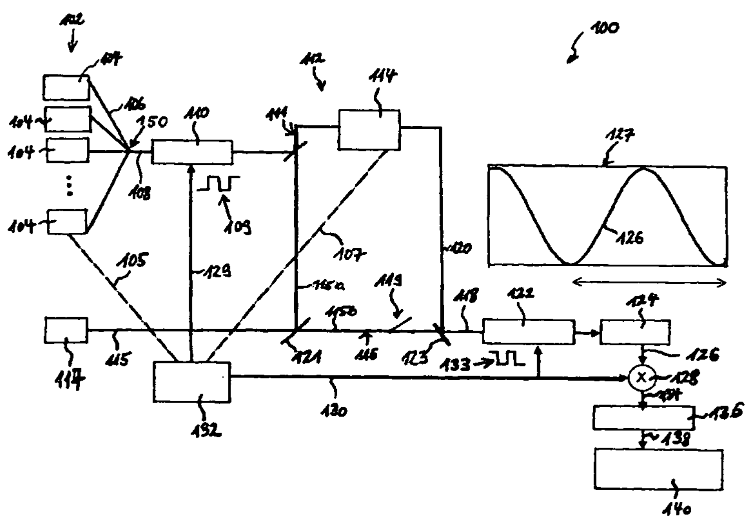
(54) Title: LOAD DEPENDENT ANALYZING OPTICAL COMPONENTS



(57) Abstract: The present invention relates to an apparatus and to a method of load dependent analyzing an optical component (114), comprising the steps of: splitting an intial signal (115) into the reference signal (115b) into and into a measurement signal (115a), intermittently providing a load signal (108) to the component (114), providing the measurement signal (115a) to the component (114), so that the component (114) can influence the measurement signal (115a) to create a signal (120) influenced by and received from the component (114), superimposing the reference signal with the signal(120) received from the component (114, to provide a superimposed signal (118), detecting the superimposed signal (118) when the loading signal (108) is not present at the component (114) to provide an information containing signal (126), and processing the information containing signal (126) to determine an optical property of the component (114) dependent on a property of the load signal (118).

WO 2004/038359 A1

LOAD DEPENDENT ANALYZING OPTICAL COMPONENTS

BACKGROUND OF THE INVENTION

The present invention relates to load dependent analyzing optical components, in particular to interferometric phase measurement of passive and active optical components.

Optical networks operating at highest bit-rates, e.g. 40 Gb/s, impose increasingly stronger requirements on the dispersion properties of all involved network elements. This implies that passive and active optical components or devices need to be characterized, in particular in terms of group delay and differential group delay. Active components can be optical fiber amplifiers, such as erbium doped fiber amplifiers (EDFA), TDFA, OFA, optical wave guide amplifiers, such as EDWA, semi-conductor amplifiers, such as SOA, and hybrid devices. Major component parameters of active devices are gain and noise figure. These parameters can be measured by indirect principles such as time-domain extinction method, signal substitution and interpolation with signal subtraction and other direct principles such as dynamic gain and noise gain profile. Passive optical devices and their dispersion relevant phase properties can be measured by modulation phase shift methods, differential phase shift methods and interferometric methods.

SUMMARY OF THE INVENTION

It is an object of the invention to provide improved load dependent analyzing optical components, in particular to interferometric phase measurement of passive and active optical components. The object is solved by the independent claims. Preferred embodiments are shown by the dependent claims.

Generally, interferometric methods used to obtain the phase properties of passive optical devices rely on the interference of a chirped laser light with its delayed signal. The present invention comprises the perception that active

components to be characterized by such interferometric methods must be loaded by a set of sources spaced in optical frequency. However, these loading sources interfere with the chirped laser in such a way, that phase properties of an active component can only be determined with significantly reduced accuracy. Advantageously, embodiments of the present invention allow for measuring the phase properties of active devices in the presence of loading sources without the aforementioned backlogs. Moreover, embodiments of the present invention provide the ability of measurements of group delay and differential group delay of active devices under load without a significantly reduced accuracy due to interference of the loading sources with the chirped probing laser signal.

Additionally, according to embodiments of the present invention the same interferometric measurement setup can be used for phase measurements, for gain and noise figure measurements, and for gain tilt and polarization dependent gain measurements, also. Therefore, embodiments of the present invention provide for a combined setup for loss, phase, gain and noise figure measurements.

The invention can be partly embodied or supported by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit. Software programs or routines are preferably applied to the realization of the inventive method.

BRIEF DESCRIPTION OF THE DRAWING

Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawing. The components in the drawing are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Features that are substantially or functionally equal or similar will be referred to with the same reference sign(s).

Fig. 1 shows a schematic illustration of an embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now in greater detail to the drawing, Fig. 1 shows a setup 100 according to an embodiment of the present invention. Setup 100 comprises a bank 102 of sources 104 providing optical signals 106 which signals 106 are combined by a coupler 150 to a resulting signal 108. Sources 104 can be distributed feedback laser sources. Resulting signal 108 is amplitude modulated with a modulation frequency 109 by an external modulator 110 controlled via connecting line 129 by a radio frequency (RF) signal source 132. Signal 108 is then added to a measurement arm 111 of an interferometer 112 as a load signal for a device under test (DUT) 114 as a transmittive component to be analyzed in a measurement arm 111.

The DUT 114 can be an amplifier, e.g. an EDFA. The amplitude of the load signal 108 should be strong enough to induce a change of the load dependent properties of the DUT 114. Preferably, the load signal 108 should induce a saturation of the DUT 114.The other arm 116 of the interferometer 112 is a reference arm 116 of the interferometer 112.

Alternatively, the loading sources 104 can be modulated directly according to dotted line 105 or the DUT 114 can be modulated directly according to dotted line 107 if a loading source or a combination of loading sources together with a coupler is part of DUT 114.

Tuned laser light 115 provided by a chirped tunable laser source 117 is applied to the interferometer 112, also. The laser light 115 is split by a beam splitter 121 into a part 115a traveling through the measurement arm 111 in which it is delayed by DUT 114 and into a part 115b traveling through the reference arm 116. A delayed signal 120 is then superimposed with the undelayed part 115b of signal 115 by a beam splitter 123 to create a resulting interferometer signal

118.

Without the load 108, the interferometer signal 118 is determined by the interference of the laser signal 115b with its delayed signal 120. Typical frequencies of the interferometer signal 118 are up to 500kHz, e.g. in the range of 100 kHz – 500 kHz. The modulation frequency 109 of modulator 110 should be significantly higher than the maximum interference signal 118 obtained without the load 108. A modulation frequency 109 of > 5MHz is feasible.

A demodulator 122 controlled via connecting line 130 by the RF signal source 132 and receiving interference signal 118 passes the interferometer signal 118 to a receiver 124 at those times according to demodulation frequency 133, where the modulator 110 switches the loading light 108 off. The load dependent optical properties of the DUT 114 have a time constant that is larger than the off-period of the modulator 110. In other words: the modulation frequency 109 is chosen much higher than the frequency with which the load dependent optical properties of the DUT 114 are expected to oscillate. Therefore, optical properties of DUT 114 can be measured during the off-period of the modulator 110 without interference of laser light 115 of tunable laser source 117 with the load signals 108.

A signal 126 of the receiver 124 is then down-converted using classical heterodyne mixing by a mixer 128 into an interference frequency range used at no load operation of setup 100. The modulated receiver signal 126 is displayed in a graph 127.

Receiver signal 126 is mixed with signal 130 of the RF signal source 132 in mixer 128. The resulting mixed signal 134 is provided to a low-pass filter 136 and the low-passed filtered signal 138 is then provided to a signal processing unit 140 to evaluate group delay, differential group delay, gain and/or noise figure of DUT 114. In an alternative embodiment mixer 128 and low pass filter 136 can be replaced by a high-speed digital receiving unit.

In reference arm 116 there can be integrated a switch 119 to simulate a non-

interferometric time domain extinction method measurement of DUT 114, also.

CLAIMS:

1. A method of load dependent analyzing an optical component (114,), comprising the steps of:

   intermittently providing a load signal (108) to the component (114),

   providing a measurement signal (115a) to the component (114), so that the component (114) can influence the measurement signal (115a) to create a component signal (120) influenced by the component (114),

   superimposing a reference signal (115b) with the component signal (120) to a superimposed signal (118),

   detecting the superimposed signal (118) when the loading signal (108) is not present at the component (114) to provide an information containing signal (126), and

   processing the information containing signal (126) to determine an optical property of the component (114) dependent on a property of the load signal (108).

2. The method of claim 1, further comprising the steps of:

   intermittently providing the load signal (108) to the component (114,) by periodically providing the load signal (108) to the component (114), and

   detecting the superimposed signal (118) during periods in which the loading signal (108) is not provided to the component (114).

3. The method of claim 1 or any one of the above claims, further comprising the steps of:

   intermittently providing the load signal (108) to the component (114) by switching the load signal (108) to the component (114, 114a) on and off, and

detecting the superimposed signal (118) during periods in which the loading signal (108) is switched off.

4. The method of claim 1 or any one of the above claims, further comprising the step of:

composing the load signal (108) by at least two loading signals (106) spaced in optical frequency.

5. The method of claim 4, further comprising the step of:

intermittently providing the load signal (108) to the component (114) by executing at least one of the following: switching the loading signals (106) on and off, modulating the load signal (108).

6. The method of claim 1 or any one of the above claims, further comprising the step of:

controlling the provision of the load signal (108) by a controlling signal (105, 107, 129).

7. The method of claim 6, further comprising the step of:

mixing the controlling signal (105, 107, 129) with the information containing signal (126).

8. The method of claim 1 or any one of the above claims, further comprising the step of:

band pass filtering the information containing signal (126) before processing the information containing signal (126).

9. The method of claim 1 or any one of the above claims, further comprising the step of:

at least temporarily switching off the reference signal to detect solely the signal (120, received from the component (114,) to perform a time

domain extinction measurement of the component (114,).

10. The method of claim 1 or any one of the above claims, further comprising the step of:

the determined optical properties comprising at least one of the following group comprising: group delay, differential group delay, loss, gain, noise figure, gain tilt, polarization dependent gain

11. The method of claim 1 or any one of the above claims, further comprising the step of:

deriving the reference signal (115b) and the measurement signal (115a) from an initial signal (115).

12. An apparatus for load dependent analyzing an optical component (114, , comprising:

an interferometer (112) comprising:

a reference arm (116) to receive a reference signal (115b), and

a measurement arm (111) to receive a measurement signal (115a) and for providing the measurement signal (115a) to the component (114), so that the component (114) can influence the measurement signal (115a) to create a signal (120) influenced and received from the component (114),

a load source (104) for intermittently providing a load signal (108) to the component (114),

a first beam splitter (121) at the beginning of the reference arm (116) and of the measurement arm (111) for splitting an initial signal (115) into the reference signal (115b) and into the measurement signal (115a)

a second beam splitter (123) at the end of the reference arm (116) and of the measurement arm (111) for superimposing the reference signal

(115b) with a signal (120) received from the component (114,) to provide a superimposed signal (118),

a detector (124) for detecting the superimposed signal (118) when the loading signal (108) is not present at the component (114) to provide an information containing signal (126), and

a signal processor (140) for processing the information containing signal (126) to determine an optical property of the component (114).

13. The apparatus of claim 12,

the load source (104) being a load bank (102) composed of at least two loading sources (104) for composing the load signal (108) by at least two loading signals (106) spaced in optical frequency.

14. The apparatus of claim 12 or any one of the above claims,

the load source (104) being composed of at least two loading sources (104) for composing the load signal (108) by at least two loading signals (106) spaced in optical frequency, and further comprising at least one of the following:

a modulator (110) for intermittently providing the load signal (108) to the component (114) by modulating the load signal (108), a first switch for switching the loading source (104) on and off.

15. The apparatus of claim 12 or any one of the above claims, further comprising:

a RF source (132) for controlling the provision of the load signal (108) by a controlling signal (105, 107, 129).

16. The apparatus of claim 15, further comprising:

a mixer (128) for mixing the controlling signal (105, 107, 129) with the information containing signal (126).

17. The apparatus of claim 12 or any one of the above claims, further comprising:

a band pass filter (136) for extracting the information containing signal (126) before processing the information containing signal (126).

18. The apparatus of claim 12 or any one of the above claims, further comprising:

a second switch (119) for at least temporarily switching off the reference signal (115b) to detect solely the signal (120) received from the component (114) to be able to perform a time domain extinction measurement of the component (114).

19. The apparatus of claim 12 or any one of the above claims, further comprising:

the determined optical properties comprising at least one of the following: group delay, differential group delay, loss, gain, noise figure, gain tilt, polarization dependent gain

20. An apparatus adapted for load dependent analyzing an optical component (114), comprising:

a first signal source adapted for intermittently providing a load signal (108) to the component (114),

a second signal source adapted for providing a measurement signal (115a) to the component (114), so that the component (114) can influence the measurement signal (115a) to create a component signal (120) influenced by the component (114),

a reference signal source adapted for providing a reference signal (115b),

a detector adapted for detecting, when the loading signal (108) is not present at the component (114), a superimposed signal (118) as a

superimposition of the reference signal (115b) with the component signal (120) to a superimposed signal (118), and for providing therefrom an information containing signal (126), and

a processing unit adapted for processing the information containing signal (126) to determine an optical property of the component (114) dependent on a property of the load signal (108).

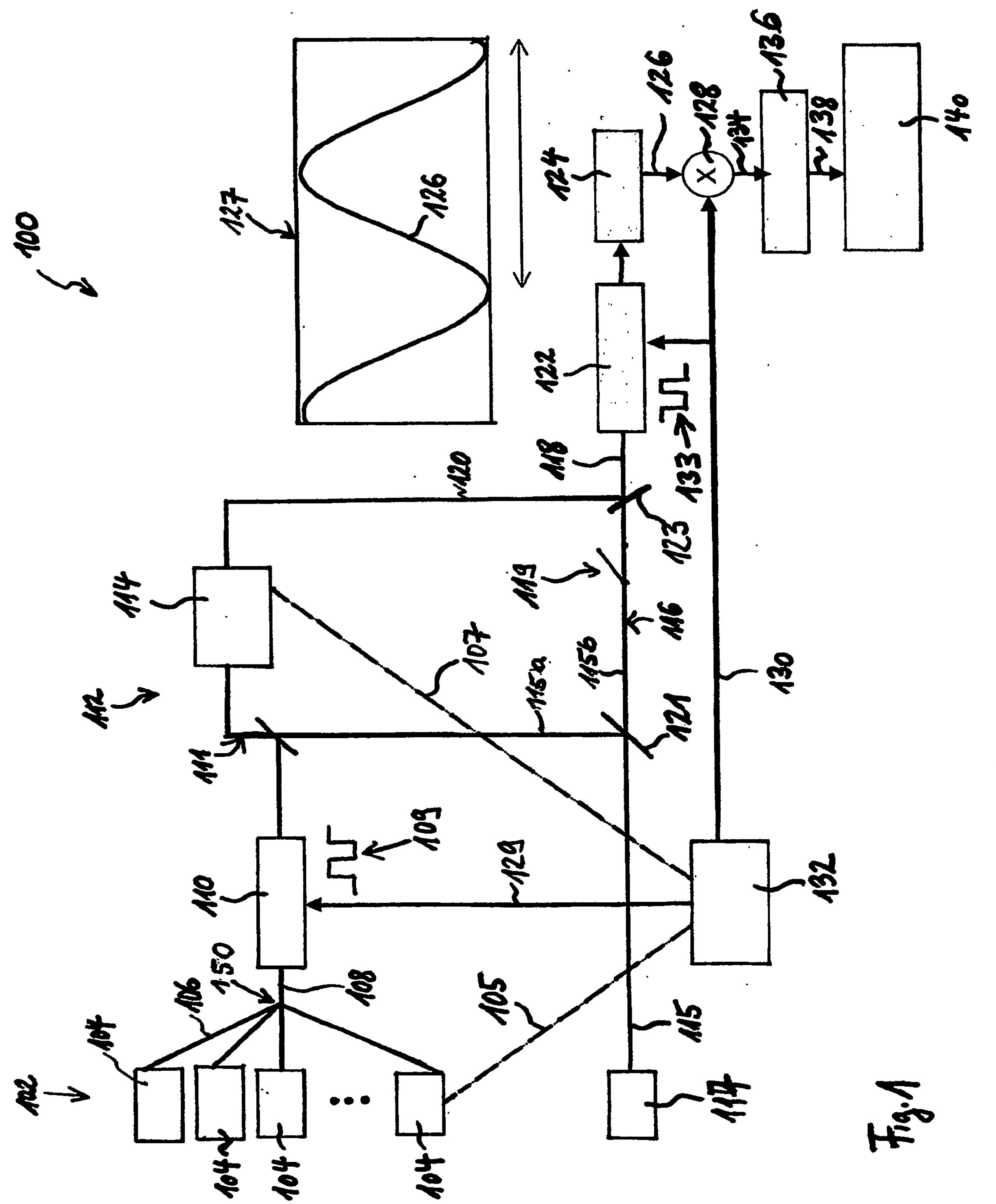

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Fig.1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/[illegible] 02/11993

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01M11/00 H04B10/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01M H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 212 003 B1 (H. KOMAZAWA ET AL.) 3 April 2001 (2001-04-03) the whole document ---	1,12,20
A	EP 1 148 664 A (ANDO ELECTRIC CO., LTD. ET AL.) 24 October 2001 (2001-10-24) the whole document ---	1,12,20
A	FLEMING S C ET AL: "MEASUREMENT OF PUMP INDUCED REFRACTIVE INDEX CHANGE IN ERBIUM DOPED FIBRE AMPLIFIER" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 27, no. 21, 10 October 1991 (1991-10-10), pages 1959-1961, XP000265678 ISSN: 0013-5194 the whole document ---	1,12,20

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
5 June 2003	18/06/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Assche, P

Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/[illegible] 02/11993

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 280 329 A (ANRITSU CORPORATION) 31 August 1988 (1988-08-31) the whole document ---	1,12,20
A	EP 1 018 642 A (ADVANTEST CORPORATION) 12 July 2000 (2000-07-12) the whole document -----	1,12,20

INTERNATIONAL SEARCH REPORT

International Application No
PCT/[illegible] 02/11993

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 6212003	B1	03-04-2001	WO	9943054 A1	26-08-1999
			JP	3322679 B2	09-09-2002
EP 1148664	A	24-10-2001	JP	2001308417 A	02-11-2001
			EP	1148664 A2	24-10-2001
			US	2001046082 A1	29-11-2001
EP 280329	A	31-08-1988	EP	0280329 A2	31-08-1988
			JP	64000438 A	05-01-1989
			US	4799789 A	24-01-1989
EP 1018642	A	12-07-2000	JP	2000199730 A	18-07-2000
			EP	1018642 A2	12-07-2000
			US	6493074 B1	10-12-2002